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Utilize BIM Technology for Achieving Sustainable Passengers Terminal in Baghdad International Airport

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ABSTRACT

The construction of airport infrastructures usually consumes huge amount of energy. In fact, the airport buildings are among the largest energy consumers entities due to their huge size and special operation pattern as well as their unique configuration that facilitate the large number of accommodated passengers. Despite the local energy shortage in Iraq in the last two decades, there is a quite scarce number of researches that deal with sustainable airport buildings. The aim of this research is to analyze the terminal building in Baghdad International Airport in order to find out the best set of modifications that result in an optimal energy consumption and least carbon dioxide emissions. The analysis was conducted by the use of Building Information Modelling (BIM) technology and the associated programs such as; Auto desk Revit 2021 and Auto desk Insight 360, in order to determine the optimal strategies by which the most applicable alternative construction materials and procedures are considered in order to obtain an environmentally and economically sustainable airport terminal buildings. By applying this analysis on Nineveh terminal building in Baghdad International Airport revealed that many alternatives are capable of making tangible reduction in the Energy Use Intensity (EUI). Such reductions are noticed when altering, in the optimum manner, the windows configurations in terms of size, glazing type, and shadings. The alteration of construction materials for walls and roofs also reduces the EUI. It was also found out that the change in lighting control systems and lighting efficiency may reduce EUI. But the major impact could be resulted when altering the Heating/Ventilating/ Air conditioning Systems (HVAC) in the optimum manner which reduces the EUI by 67.15kw/m^2/year, and the proper use of photovoltaic panels which provides a sustainable electricity and reduces EUI by 57.08 kWh/m^2/year. Accordingly; in the quest of the best procedure to develop a sustainable terminal building, it is highly recommended to alter the HVAC systems and the utilization of the photovoltaic panels on rooftops.

1. Introduction

Airports are an essential part of the complex international transportation system that facilitates and promotes the movement of passengers, cargo, and tourists around the world [1]. They have an impact on the atmosphere as well as on the people who live nearby. As a result, airports need to be socially and environmentally conscious. Many airports have started working to create a more sustainable climate [2]. Baghdad International Airport, as the major hub in Iraq, was designed and constructed in the seventies of the last century. The growing demand in the last two decades reached almost the total capacity of the passenger terminal building [3]. Although, its design was state of the art but very little attention was paid for the sustainability

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measures as in many similar projects conducted back then in that era. In the following four decades and due to the unpleasant circumstances surrounded the country and specially the capitol Baghdad, there was a very limited improvements in the existing infrastructures regarding sustainability measures. The airport was one of these infrastructures if not the worse for being the theater for many military and insurgency actions. In this research, an analysis is conducted on a unit terminal building in Baghdad International Airport using the BIM technology in association with Auto desk Revit 2021 and Auto desk Insight 360 in order to determine the most effective measures, such as the alteration of some construction materials, adding certain structures, or changing some equipment, by which the environmental and economic sustainability of the building could be improved. The finding of this research my represent a guide for the airport stakeholders and decision makers for improving the airport buildings sustainability.

2. Literature review

There has been a significant increase in public awareness of the environmental consequences of human activity over the last 20 years or so [4].

Many researchers have concentrated on improving the energy efficiency of airport structures. For example,[5] The feasibility of using BIM in sustainability analysis has been investigated.[6] this paper focuses on improving the sustainability of airports – whether they are existing, expanded, or new. Using a scenario-based approach, we investigated the feasibility of options for encouraging more sustainable airports, focusing on airport surface access transport and terminal building design.

The ability to meet the needs of modern human growth without jeopardizing future generations is the widely accepted definition of sustainability [7]. Airports are networks that are a part of today's society and play an important role in meeting the need for mobility [8]. The future of airport planning is the development of sustainable airports.

In 2010, buildings accounted for nearly 32% of global energy consumptions and 19% of energy-related greenhouse gas emissions [9]. Global warming has a harmful impact on the environment and societies, according to these assessments. As concerns about global warming grow, it's no surprise that the construction buildings increasingly try to meet the need for energy efficient structures [10]. The electricity crisis in Iraq creates air pollution and low quality, which has a significant impact on the safety and health of Iraqi inhabitants [11]. Building information modeling (BIM) is an integrated and comprehensive system including whatever is related to a construction project and its stages. It represents a unified database for all project data through which project documents are available to all stakeholders [12].

The usage of traditional 2D (CAD) planning process do not allow for early judgments; energy and performance analyses are often undertaken after the preparation of architectural and construction design documents [5]. Building information modeling (BIM) is a novel technique that combines a variety of tools for assessing the energy performance of a building [13]. BIM technology offers the possibility of designing virtual parameters corresponding to the real working environment, making it possible to solve all the difficulties upstream of the project [14]. The usage of computer technology can substantially aid in the facilitation and improvement of labor [15]. Building energy modeling (BEM) is a new methodology based on building information modeling (BIM) [16]. The design team can benefit from BEM when utilized at the design stage, where design alternatives in terms of energy consumption and thermal comfort can be explored and evaluated [17]. Building Information Modeling (BIM) is a comprehensive and coherent system for all aspects of a construction project, consisting of a set of effective policies, procedures, and computer applications that improve the level of performance in a construction project throughout its life cycle. [18]. Information technology and its application have resulted in enormous development in the construction industry during the last decade. The main reason behind this evolution was the incorporation of Building Information Modeling (BIM) to be an inefficient construction approach. BIM is now globally considered to be the tool of transforming the construction process to new era [19].

The terms “green building” and “high-performance building” have been used interchangeably [20]. In accordance with the Energy Independence and Security Act (NIBS 2011), A high performance building is one that continuously improves and integrates all of a building's key performance attributes throughout its life cycle. This encompasses not only environmental sustainability (for example, energy conservation), but also cost-benefit analysis, occupant productivity, and operational factors. As a result, the optimization and integration of various building systems is critical to the success of a building.

The construction industry is responsible for a variety of negative impacts on the environment, leading to increased demand for sustainable buildings. There are many methods of Building Sustainability Assessment (BSA) available that allow designers to assess and improve the level of sustainability of a building.

Climate change is one of the most serious threats to the aviation industry, and more particularly to the ability of the airport industry to grow and operate in the future.[21]. Utilizing building information modelling (BIM) and considering the data of the experimental part of this study, Autodesk Revit software v.2016 was used to model and evaluate the new alternative building units [22].

As a result of this concentration, the airport industry faces the effects of increasing environmental stress [23]. As a result, there has been growing interest in the impact of airports on the environment, and airports are becoming more environmentally friendly. [24]. Airports used solar installation where is one of the most energy-saving measures. Photovoltaic panels are installed on the roofs of the airport buildings. Other measures of energy saving include insulating buildings and renovating LED lighting.[25].

Airports require a steady supply of energy throughout the year in order to keep operations running and meet the needs of key stakeholders.

Airports are energy intensive regions [26]. That's all. The high energy demand is due to the large buildings (passenger lounges and non-passenger spaces) equipped with heating and air conditioning systems. Lighting equipment, electricity, and energy needs of the many facilities located in the airport area [27]. Air conditioning systems account for a significant portion of the airport's energy consumption. [28]. Air conditioning, cooling, and heating consume approximately 70% of the energy consumed in terminals. This rate may be higher in cold-weather countries[26].

In [29] Investigate the feasibility of BIM. Adoption in the Mideast as well as how to identify the benefits of BIM tools to facilitate sustainable principles The experimenter used a survey questionnaire and the results showed that majority of participants use presently BIM technology in their projects, and nearly a third of respondents use sustainable concepts. [29] Analyze various design criteria (exterior wall materials, roof components, and a variety of window / wall ratios) to allow architects and designers to be using technology to enable sustainable energy consumption in buildings. as a result of evolution of options available, such as the relationship between the window and the wall. [30] The researcher discovered that double-glazed windows contribute the most to energy consumption reduction by studying the effect of various green envelopes on energy efficiency and consumption.

In [31] In recent years, a Iraqi construction sector has made a number of factors have contributed to high power consumption, that has had a harmful effect on the environment, as architects and designers depended on traditional techniques two - dimensional plans and expertise. The authors of this analysis attempt to identify the various strategies and tools that BIM provides to improve a building's sustainability beginning with the design phase.

3. Research methodology

From the previous studies related to BIM technology and considering various methods to achieve energy management of the building, the research framework is developed as shown in

Fig (1). The research methodology mainly includes two parts:

3.1 Part one (theoretical study)

A literature review is conducted for previous studies related to the scope of research, including books, papers, websites, and theses.

3.2 Part two (practical study)

Which is mainly conducted on the case study terminal building in Baghdad International Airport. This terminal consists of three identical buildings, the study for each one of them may represents the other two buildings. Among them the Nineveh building is currently open for public service and all the traditional paper drawings are available what may facilitate conducting this study in which the practical part includes the following:

1. Select the case study and gather project-related Data (Traditional drawings).
2. Create 2D model by using Autodesk AutoCAD 2021 Program.
3. Using Autodesk Revit 2021 to create a 3D BIM model of the project.
4. Create spaces for all terminal, as shown in Fig 2.
5. Change the energy settings and import some information, such as the site, nature of the project, type of air condition and hours of work, etc.
6. Create an energy model, as shown in Fig 3.
7. Calculate Heating &cooling loads and Generate model, as shown in Fig 3.
8. In Rivet 2021, select the optimize panel to operate an energy analysis in the Insight 360 web and upload the results to Green Building Studio.
9. Energy analysis, with results displayed in Autodesk Insight 360 cloud and green building studio (GBS).
10. The analysis results show the various design options, their effect on the energy use intensity (EUI) and annual energy consumptions.
11. In Autodesk Insight 360 cloud, illustrate and evaluate sustainable design options that improve energy efficiency.

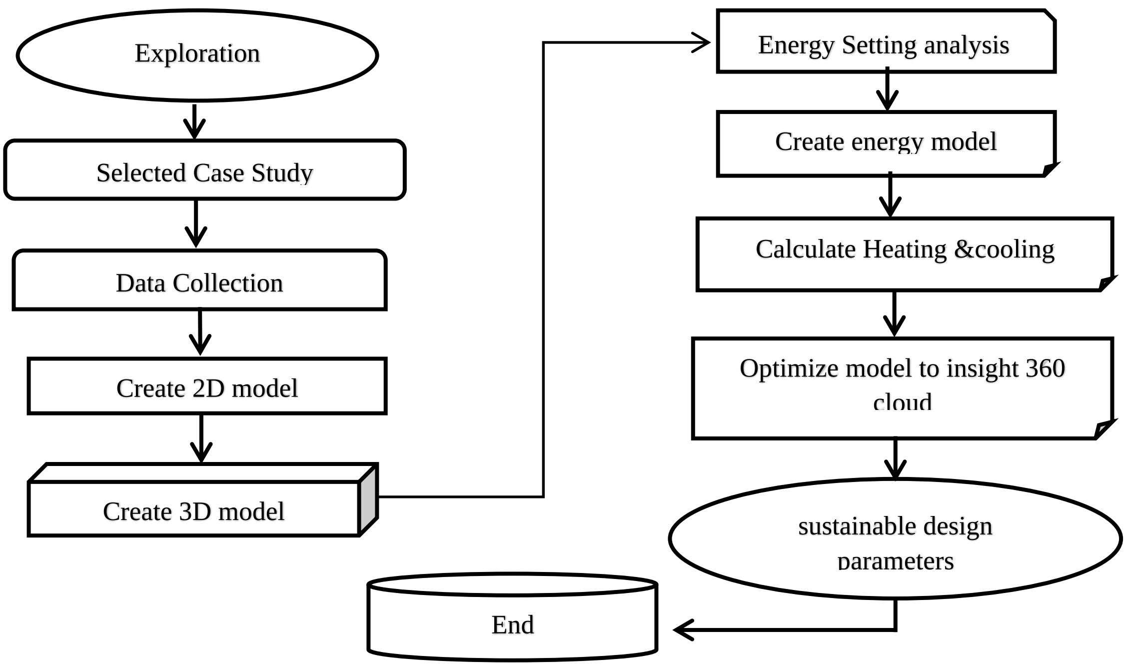

Figure 1. Research methodology framework

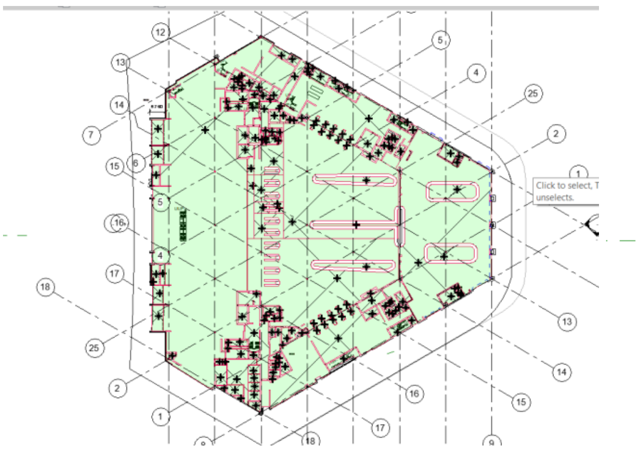

Figure 2. Spaces and energy model of the terminal

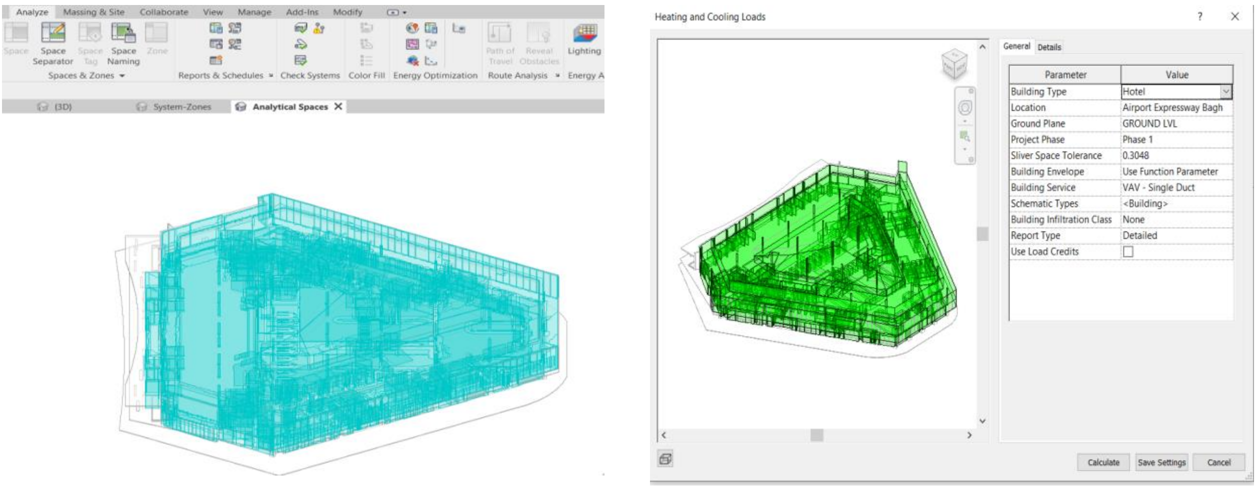

Figure 3. Create energy model and heating & cooling of case study

4. Case study

The selected case study is the terminal building in Baghdad International Airport. The terminal's basic form is built on a 19-meter-long equilateral triangular shape, which is repeated as a foundation to generate functional and structural formations. This building consists of three floors (Two floors of the building were studied due to reservations made by the airport administration on basement data for security reasons). Two floors with a total area (24,789 m^2). The airport was designed by a British consultant (Monsal), and it was built by two French businesses (Fougerolle and Spie Patignolles). Fig 4 below illustrates traditional maps of case study.

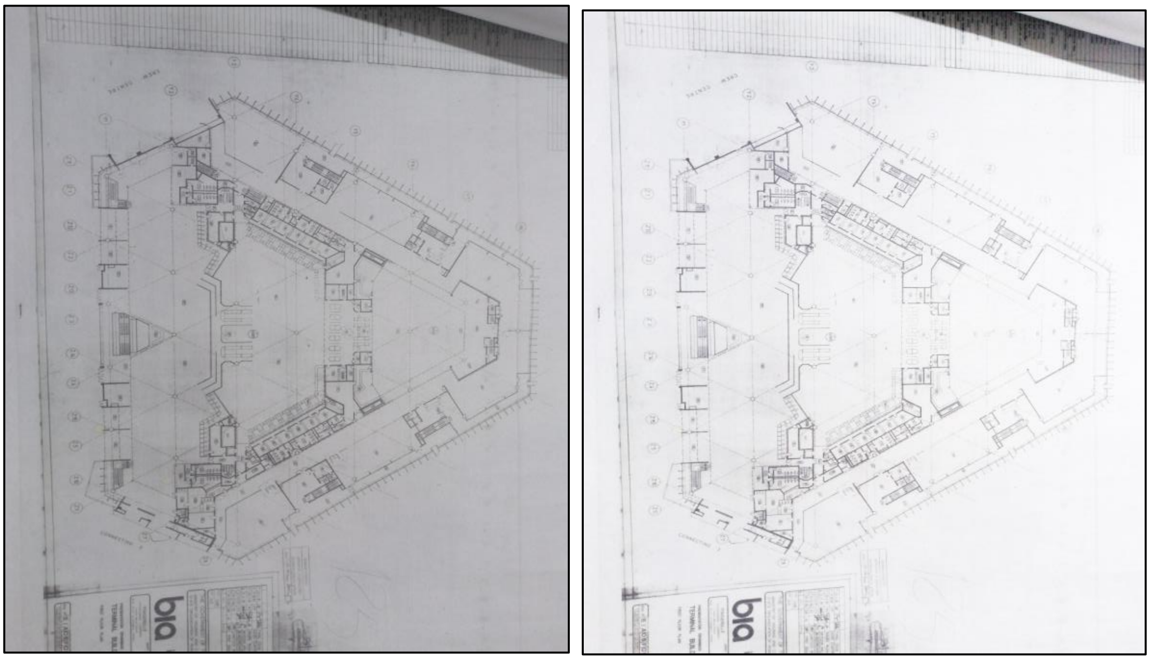

Figure 4. Traditional maps of Nineveh Terminal (airport technical library)

4.1 Create 2D and 3D model of case study

A two-dimensional map model is created using AutoCAD 2021 as shown in Fig 5 below, where the data was taken in the form of paper maps, and because paper maps cannot be used in Revit software, where it depends on entering the plans in two-dimensional format and then making a three-dimensional model of the building. After completing the 2D model of design work, a 3D model was created using Revit 2021such as shown in Fig 6 below.

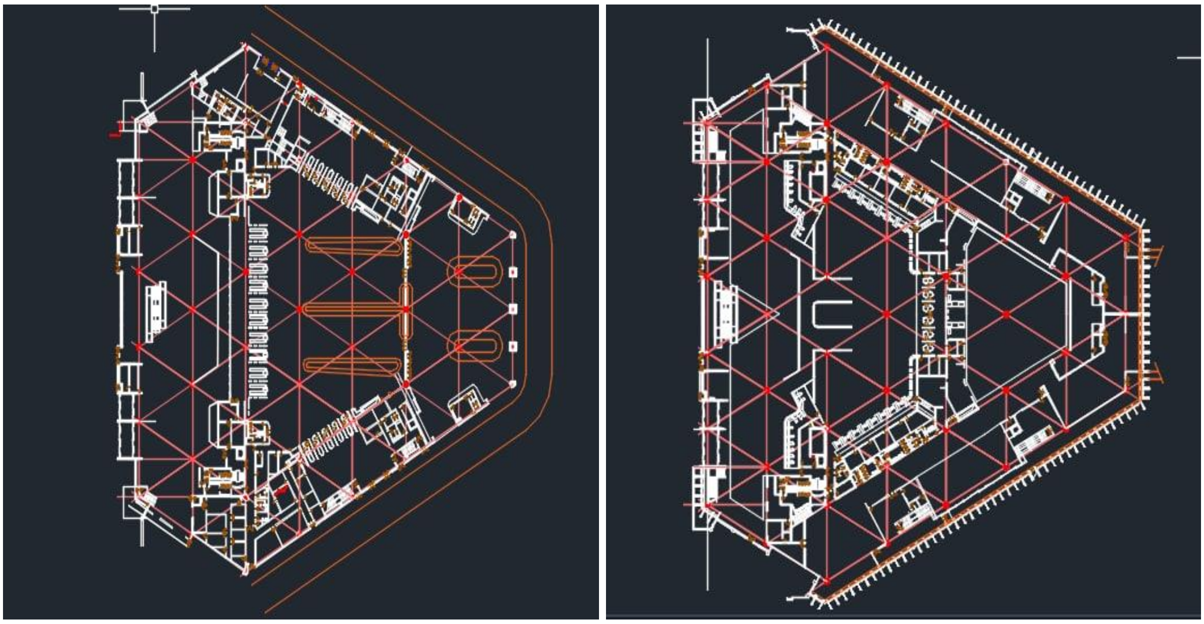

Figure 5. Cad drawings of case study

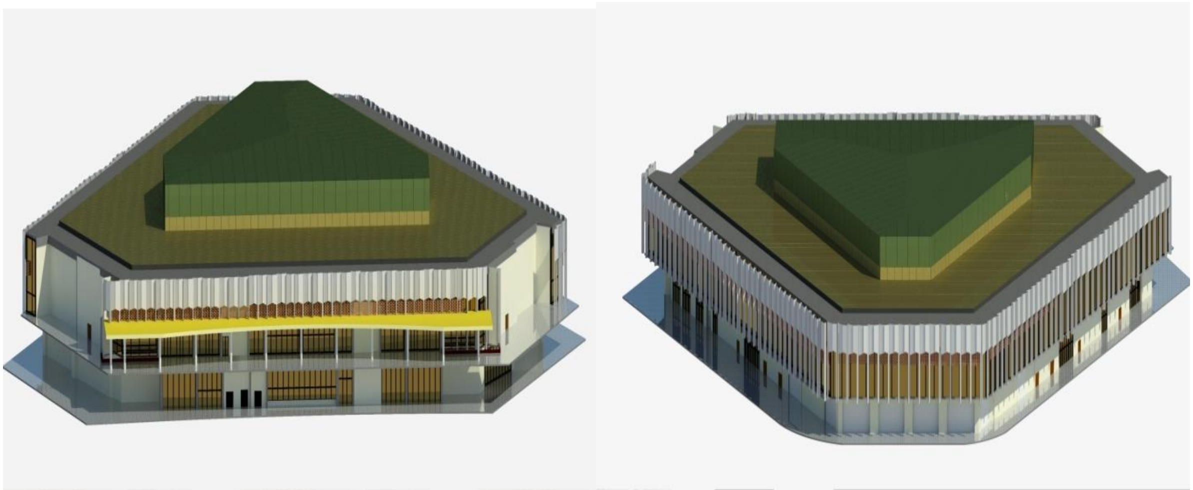

Figure 6. Rendering of case study

5. Findings and discussion

Results of this analysis are based on the energy settings, in Revit 2021 as well as the selected scenario in the web of Autodesk Insight 360. Fig 7 shows the model of case study in the Insight 360 cloud.

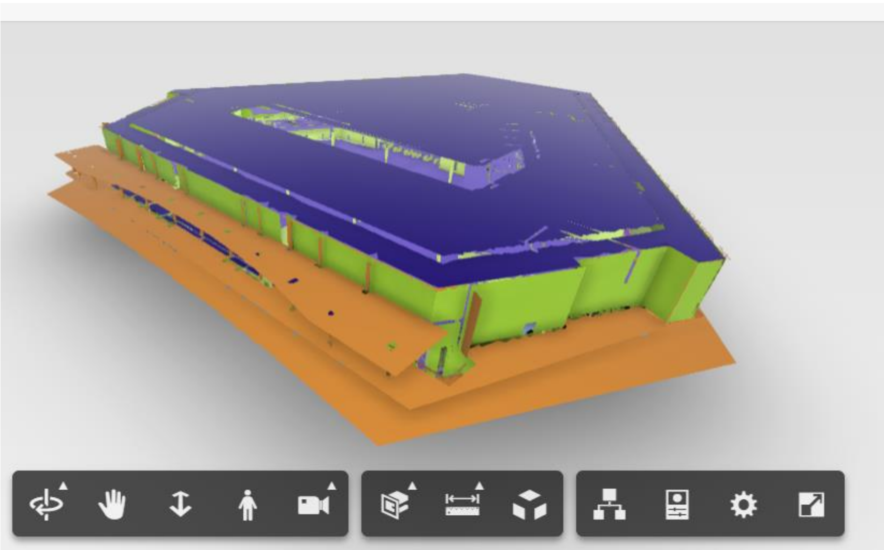

Figure 7. 3D model in Insight 360

Results illustrated the following:

5.1 The orientation of the building

The orientation is considered into account in building design as it plays an important role in reducing energy consumption, natural ventilation and increasing daylight performance inside the building. Insight 360 analysis assists the designers and architects in determining the best orientation for a building in order to reduce energy consumption. Fig 8 explains that the 315° trend is more efficient than the other trends in terms of energy consumption, with a decrease in energy intensity of around 0.14 kWh / m^2 / year. In this analysis, BIM is a function as a model value.

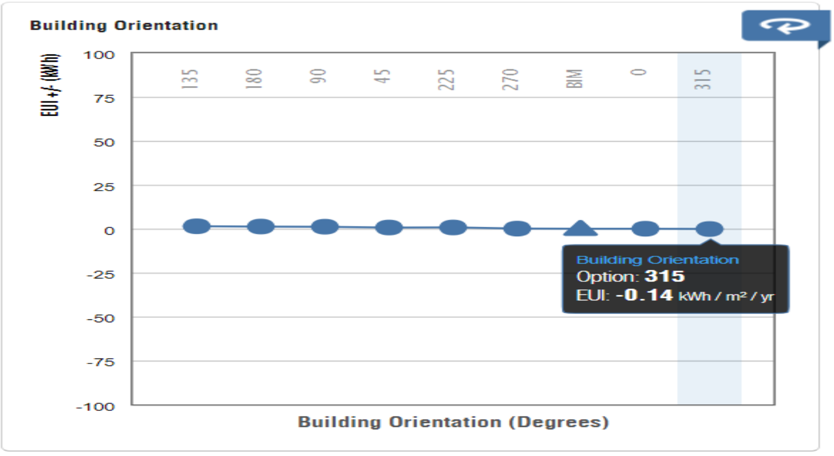

Figure 8. Building orientation

5.2 The Window-to-Wall Ratio (WWR)

Window/Wall ratio is calculated because it plays a critical role in reducing energy consumption. Fig 9 and Fig 10 show that using a window / wall ratio of 0 % on all walls reduces the energy intensity to about 0.04 kWh / m^2 / year; This percentage is low because the airport wall is a curtain wall on each side.

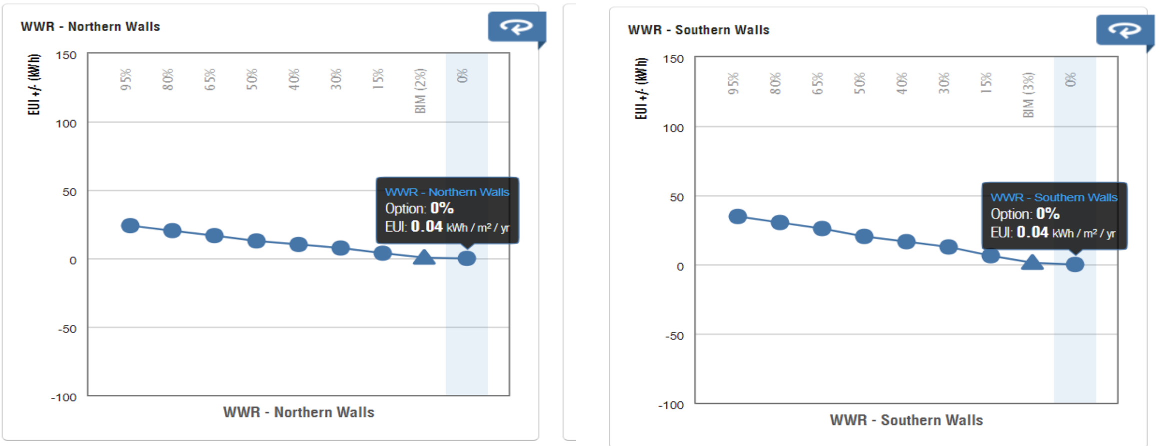

Figure 9. The WWR in southern & northern walls

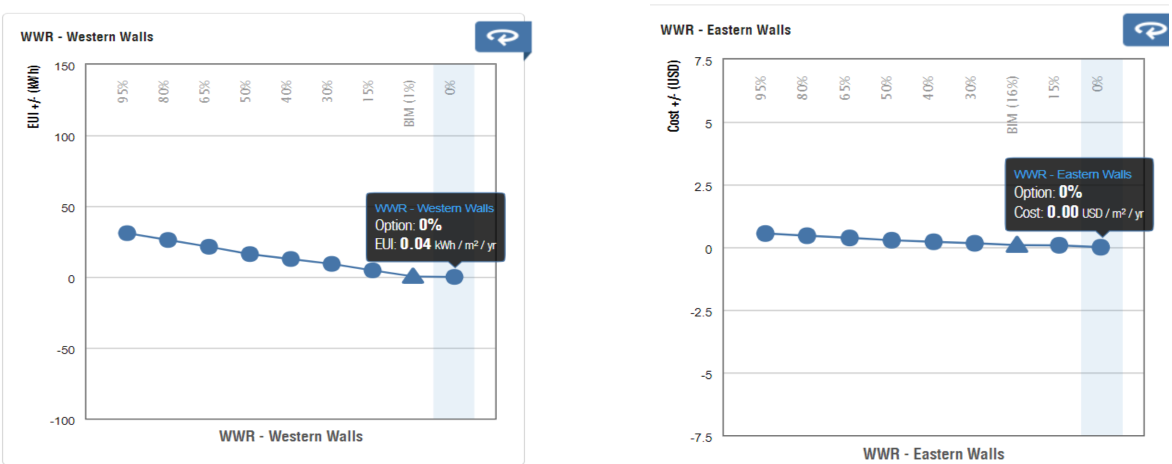

Figure 10. The WWR in western & eastern walls

5.3 Type of window glass

The type of glass is considered in the design of buildings as it plays an important role in enhancing the energy efficiency. Fig 11 explain the using of triple Low-E glazing in the windows of the south wall, where reducing the energy intensity by approximately 8.57 kWh/m^2/year. In addition, the type of glass used in the windows in the north wall had a significant impact on energy intensity, as the use of Triple Low-E glazing reduced the energy intensity by approximately 3.78 kWh/m^2/year. Fig 11 shows the effects of different types of triple glazing using in south & north walls on energy consumption compared to single glazing, which increases energy intensity. Fig 12 explain the use of triple Low-E glazing in the windows of the west wall reduced the energy intensity by about 6.76 kWh/m^2/year, while the using of triple Low-E glazing in the windows of the east wall reduced energy intensity by approximately 1.95 kWh/m^2/year.

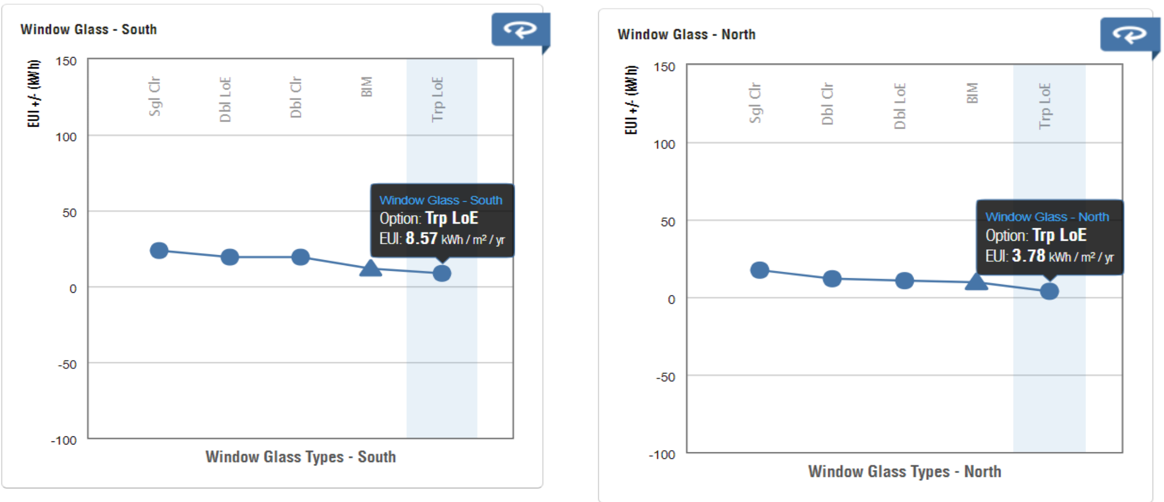

Figure 11. Type of window glass in south & north walls

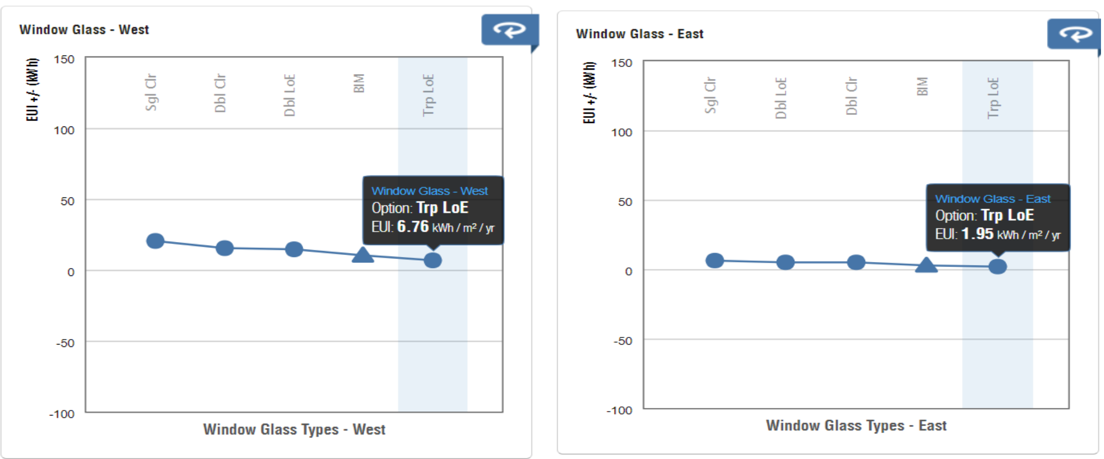

Figure 12. Type of window glass in west & east walls

5.4 Window shades

Fig 13 shows the result of using shades has a role in energy reduction, with the greatest effect observed in the south, north and west walls, where the use of blinds (1/3 height) reduces the energy intensity of about 15.65 kWh/m^2/year. While the north walls reduce the energy intensity by about 10.42 kWh/m^2/year. Figure 14 shows that the use of awnings on the west walls has a greater impact than on the east walls, with a decrease in energy intensity of around 13.34kWh/m^2/year.

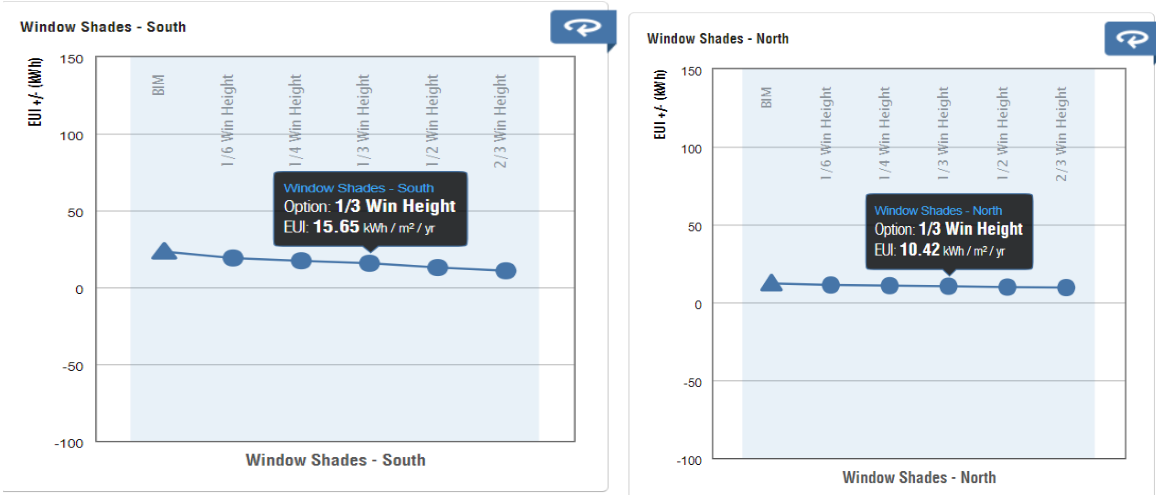

Figure 13. Window shades in south & north walls

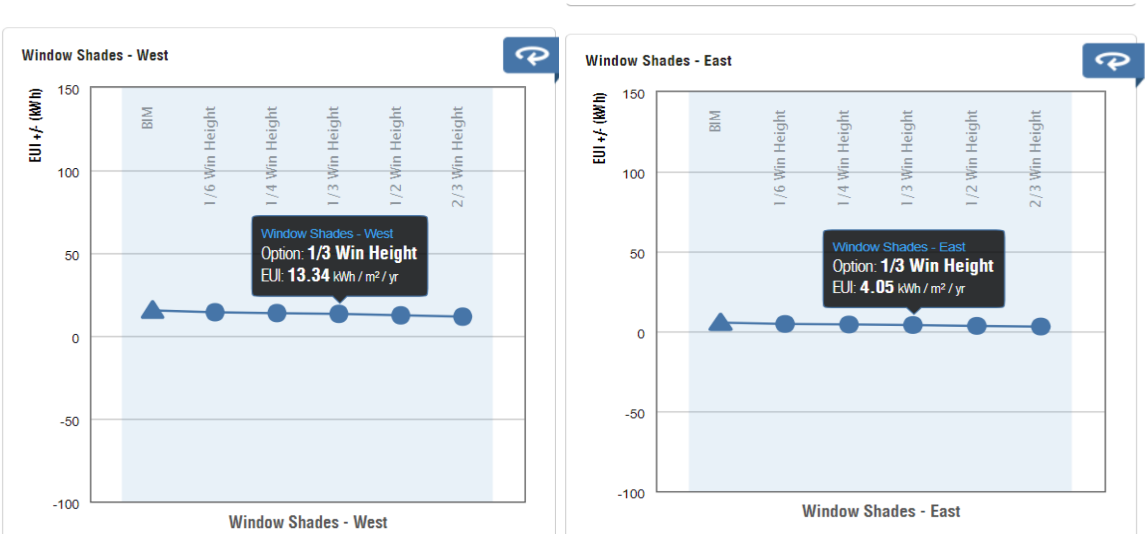

Figure 14. Window shades in west & east walls

5.5 Wall construction

The type of wall is taken into account in the design of buildings as it plays an important part in reducing energy using. Fig (15) explain the various types of construction walls in sustainable buildings and their effects on energy intensity. Results of this analysis shows that, the use of the ICF (Insulated Concrete Formwork) wall reduced the energy intensity by approximately 8.95 kWh/m^2/year. Fig 15 the impact of wall insulation is explained by the fact that it increases the thermal resistance of the wall, which has a significant impact on energy consumption.

Insulated concrete wall, (ICF):

Insulated Concrete Forms (ICF) produce cast-in-place concrete walls sandwiched between two layers of insulation. These systems are powerful and energy efficient. Common applications for this method of construction are low rise buildings, with real estate uses ranging from residential to commercial to industry. Traditional finishes are applied to the interior and exterior faces so that the buildings resemble the typical masonry, although the walls are generally thicker.

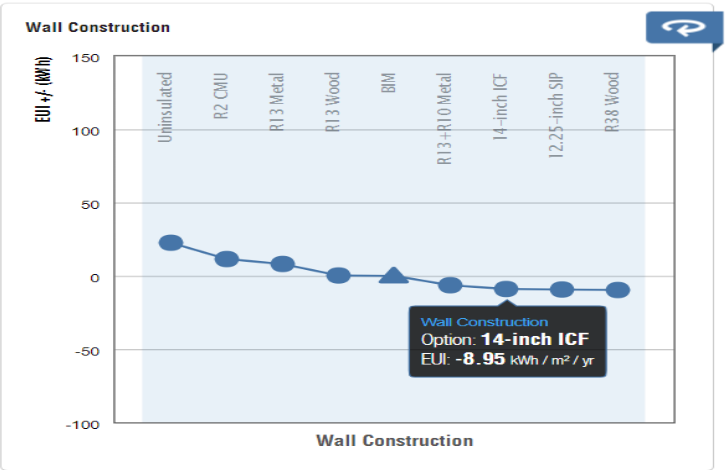

Figure 15. Wall construction type

5.6 The roof construction

This analysis illustrates various types of insulation roofs and their effects on energy intensity. Fig 16 explain that the thermal insulation rate used in the roof affects the energy intensity, with the best result obtained when the insulation rate is R60, which reduces the energy intensity by about 2.87 kWh/m^2/year where the R-value is a measure of the amount of insulation used. Table (1) shows the different types of heat-resistant roof constriction (R). (Taha, Hatem and Jasim, 2020).

Table 1: Roof construction type and heat resistance (R)

Roof Construction Name	Roof Construction	R-Value (hft^2°F/BTU)
Uninsulated	R0 over Roof Deck	1.33
R10	R10 over Roof Deck	11.75
R15	R15 Wood Frame Roof	15.61
R19	R19 insulation Wood Frame Roof	16.39
R38	R38 Wood Frame Roof	42.57
R60	R60 Wood Frame Roof	66.23
10.25-inch SIP	Structurally Insulated Panel (SIP) Roof 10.25 inch thick (260mm)	37.71

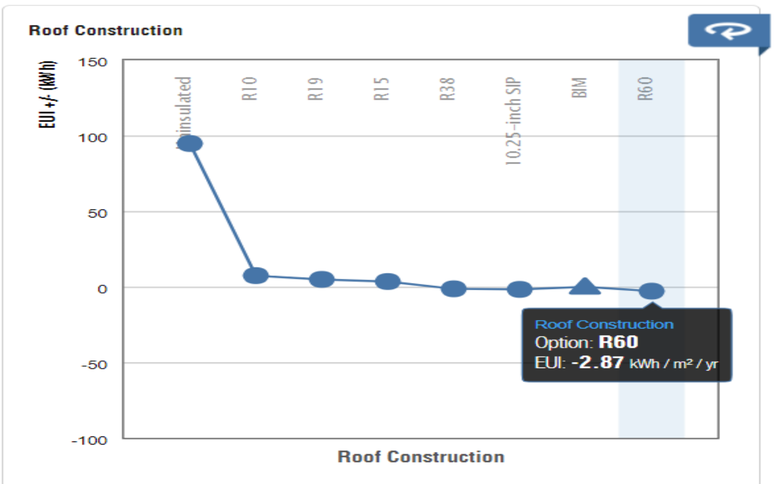

Figure 16. Roof construction type

5.7 Lighting efficiency

The power consumption of electric lighting per unit floor area is represented. Fig (17) shows that lighting efficiency has a significant impact on energy use intensity. Using lighting efficiency 7.53 w/m^2 reduces energy use intensity by approximately 11.86 kw/m^2/year.

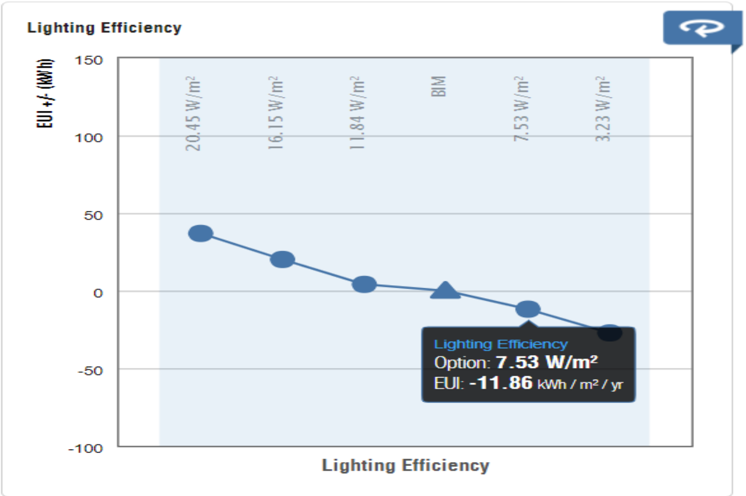

Figure 17. Lighting efficiency

5.8 Lighting control system

This enhancement included the installation of a lighting regulation system that combined presence detectors and twilight sensors to optimize electricity consumption. Fig (18) shows that using daylight and occupancy controls reduces energy use intensity by approximately 4.20 kwh/m^2/year. The daylight control system includes not only daylight openings like the skylights and windows, but also daylight sensitive, lighting control. When appropriate ambient lighting is provided only by the daylight, this system has the potential to reduce the energy consumption of electric lighting.

Occupancy control system: This lighting system is based on occupancy sensors, which detect when a space is unoccupied and automatically turn off (or dim) the lights, saving energy. When the device detects the presence of people, it may also turn on the lights automatically, providing convenience as well as potential security. Daylight and Occupancy control system: This system includes the previous two types shown above.

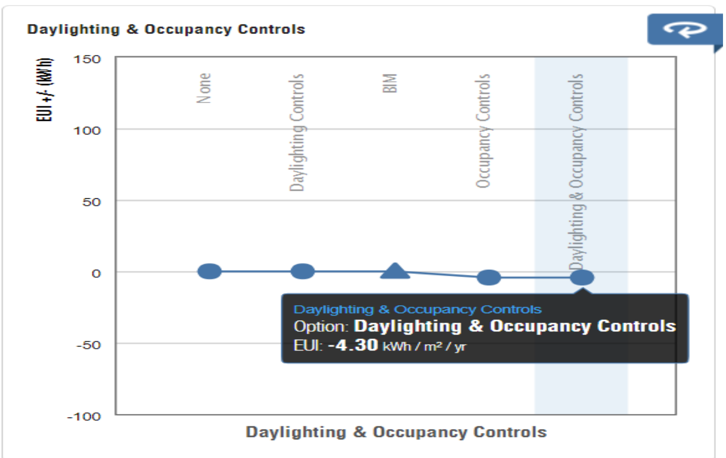

Figure 18. Daylighting & occupancy control System

5.9. Plug load efficiency

This analysis shows different types of charging efficiency of components used by equipment, such as computers and small household appliances; With the exception of lighting, heating and cooling equipment; It shows how they affect energy intensity. For example, using plug load efficiency 10.76 w/m^2 reduces energy use intensity by approximately 128.43 kw/m^2/year, as shown in Fig 19.

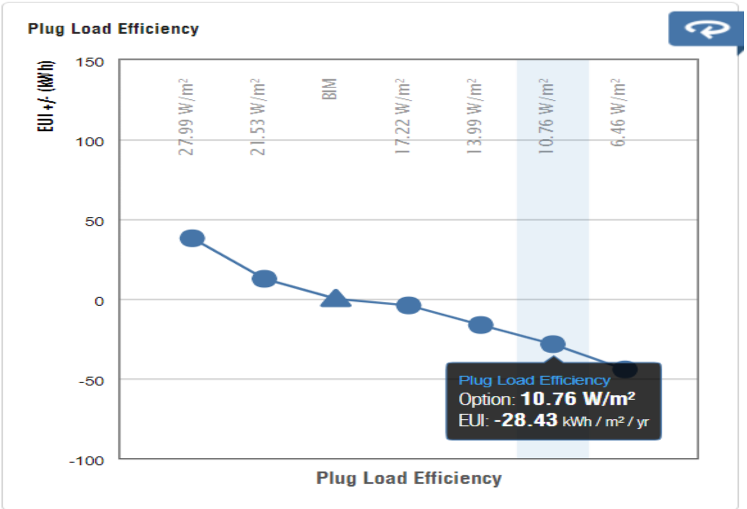

Figure 19. The Plug load efficiency

5.10. HVAC (Heating, Ventilation, and Air Conditioning) System

HVAC systems are one of the most important energy-consuming components. HVAC systems have an effect on indoor air quality and building air temperature. The effect of a different type of HVAC system on the intensity of energy use is illustrated in Fig 20. The result of this analysis shown a package terminal heat pump (PTHP) that reduces energy use intensity by approximately 67.15kw/m^2/year. Table (2) shows HVAC system and type (Taha, Hatem and Jasim, 2020).

Table 2: HVAC system and type

Name	HVAC
ASHRAE Package System	PSZ, ASHRAE 90.1-2010, 11 EER, 70F economizer
High Eff. Heat Pump	HP, 17.4 SEER, 9.6 HSPF, Electric Heat
ASHRAE Heat Pump	HP, ASHRAE 90.1-2010, 9.5 EER, COP 3.2 Electrc Heat, 70F economizer
High Eff. Package System	PSZ, small unit, 20 SEER 85% AFUE
ASHRAE VAV	VAV, ASHRAE 90.1-2010, COP 6.10 Chiller, Gas Boiler, 75F economizer
High Eff. VAV	VAV, Unerfloor Air Distribution, COP7.5 Chiller, 95% Eff. Gas Boiler, economizer
ASHRAE Package Terminal Heat Pump	PTHP, ASHRAE 90.1-2010, 11.9 EER
High Eff. Package Terminal AC	PTAC 12.7 EER, 90.4% Gas Boiler

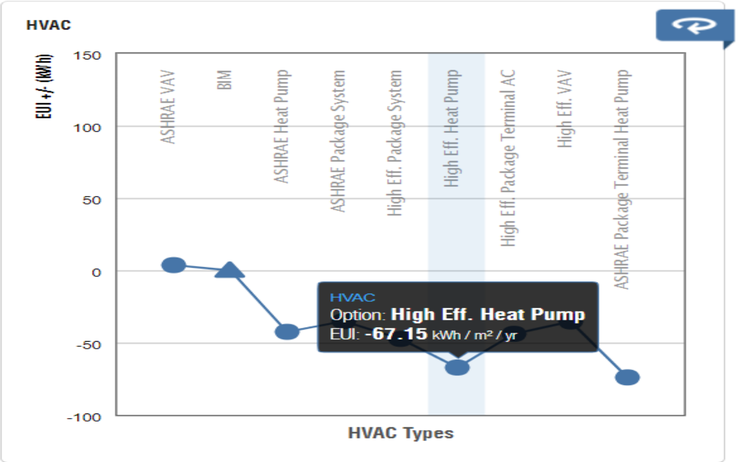

Figure 20. HVAC System types

5.11 Energy operating schedule

This analysis illustrates various types of building operating schedules and the importance of their effects on the energy use intensity; for example, using operating schedule (12/5) reduces energy use intensity by approximately 64.86 kw/m^2/year, as shown in Fig 21. Where the operating schedule is given in hours per day, 12 is the number of operating hours in a day, and 5 is the number of operating days.

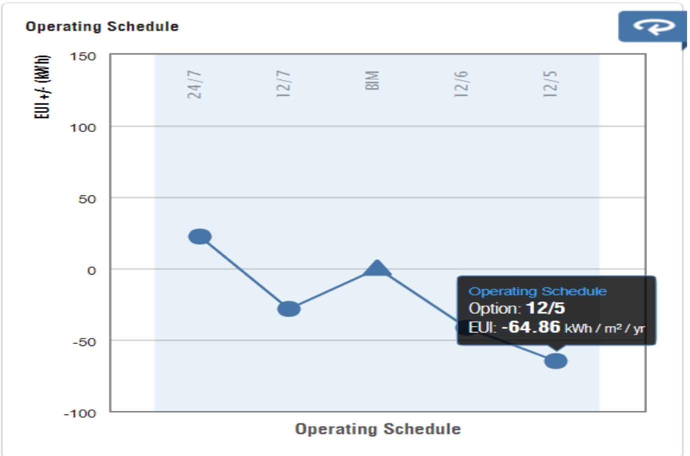

Figure 21. Energy operating schedule

5.12 Photovoltaic (PV) panels

Solar panels are one of the most important sources of renewable energy production in the world. The web Insight 360 analysis allows to know the impact of the use of photovoltaic panels on energy intensity. Fig 22 shows that photovoltaic panels have a significant impact on the energy intensity, with a decrease in energy intensity of around 57.08 kWh/m^2/year.

PV - Panel efficiency: The proportion of solar energy converted into alternating current. High efficiency panels are more expensive, but they produce more energy in the same amount of space.

PV - Payback limit: The default age of panel PV - Roof Cover: This term refers to the area of the roof that is used for photovoltaic panels, assuming an access area for maintenance, roof equipment, and system infrastructure.

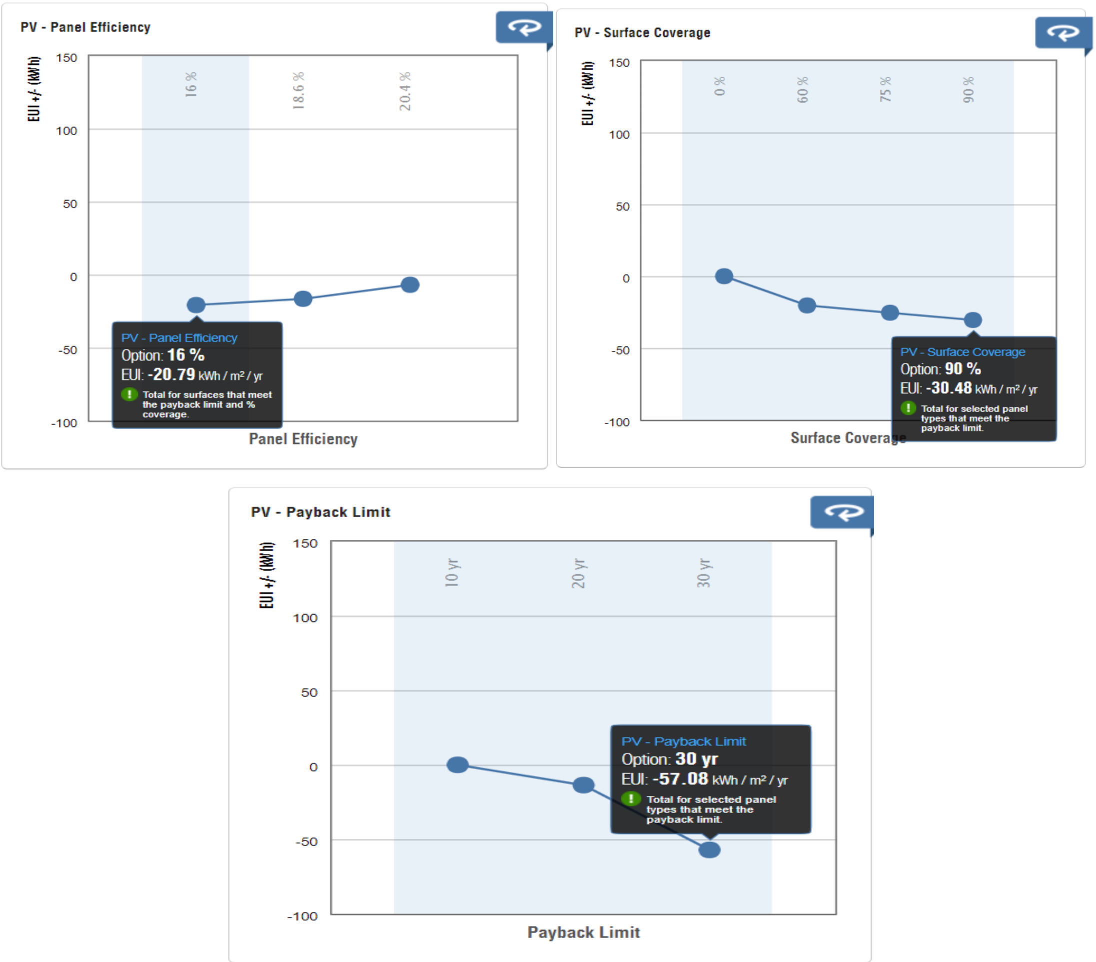

Figure 22. PV panels

As previously stated, this analysis provides designers and architects with a better understanding of the design elements that lead to better results during the building's life cycle and, thus, lead to design of the sustainable buildings; most of the elements have a significant impact on reducing energy use intensity, such as photovoltaic panels, HVAC system, operating schedule, and plug load as shown in Fig (23).

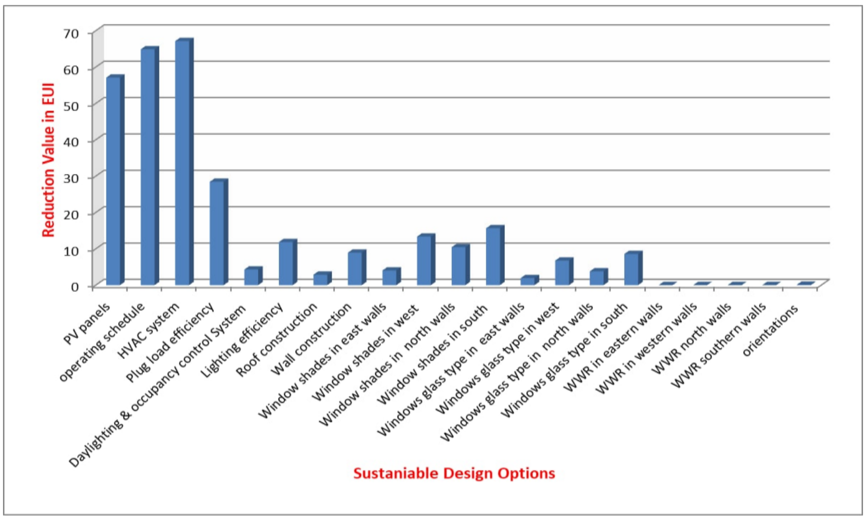

Figure 23. Model history of sustainable design options

6. Conclusions

In this paper, the Baghdad International Airport terminal building Nineveh has been analysed by the use of BIM technology. The traditional 2D drawings of the building were transformed into electronic version in Auto Cad 2D and then a 3D version of them were produced by utilizing the Revit 2021 which enabled the use of the web Autodesk Insight 360 by which multiple scenarios were selected and various alternative materials, equipment, and procedures were studied in order to come up with the most practical strategies to improve the energy consumption of the building. The analyses reveal that:

- The orientation of building, the type of glass and window/wall ratio plays a mild role in reducing energy consumption.
- Using shades has a role in energy reduction, with the greatest effect observed in the south, north and west walls, meanwhile the type of walls and roofs installations play an important part in reducing energy using.
- The power consumption of electric lighting per unit floor area is represented in this work shows that lighting efficiency has a significant impact on energy use intensity, also the installation of a lighting regulation system that combined presence detectors and twilight sensors optimize electricity consumption. The types of charging efficiency of components used by equipment, such as computers and small household appliances shows how they affect energy intensity.
- HVAC systems have the most important energy-consuming impact. HVAC systems have an effect on indoor air quality and building air temperature. The result of this analysis showed that the package terminal heat pump (PTHP) that reduces the EUI by approximately 67.15kw/m^2/year.
- The use of photovoltaic panels has a significant impact on the energy intensity use, with a decrease in EUI of around 57.08 kWh/m^2/year.

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